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LIBERALIZATION OF THE CHILEAN ELECTRICITY SYSTEM AND ITS EFFECTS ON ENVIRONMENTAL PERFORMANCE

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INTRODUCTION

This paper presents a detailed description of Chile's deregulation efforts in the electrical sector. Its aim is to examine in a structured way, the main environmental implications of this process and the expected trends, given the environmental legislation and institutionality. Chapter 1 presents a general description of Chile's pioneering efforts in deregulating its electrical sector. As is well known, the initial success promoted similar efforts in many other countries of the world. Chapter 2 describes Chile's main electrical systems. The importance of hydroelectricity is discussed, together with the increasing importance of natural gas. The impressive growth rates of the sector are presented, and also the increasing emissions of gases related to thermal generation. Chapter 3 describes the operation of the deregulated system. In particular, a detailed account is given of each of the system's segments: generation, transmission and distribution. Chapter 4 presents de regulatory frameworks that affect the environment, in particular the electrical law and the environmental framework law. Chapter 5 discusses the main problems relating to a better environmental stewardship in Chile's electrical system. Finally, chapter 6 presents the main conclusions.

1. CHILE´S PIONEERING DEREGULATION EFFORTS

The Chilean experience demonstrates how the process of electricity deregulation can get started, not so much out of a desire to reshape the electric sector as such, but because of broader economic and political aims. Whatever the reasons behind its deregulation, its success has pushed other countries in the same deregulatory direction.

For all practical purposes, the story begins in 1977, when Bruno Philippi, an engineering professor at Catholic University of Chile and a Stanford Ph.D. in engineering took over as executive director of the newly created National Energy Commission (henceforth CNE). At that point the main objective of the government was to rationalize and bring order to the chaotic price system prevailing in the energy sector as a whole.

At the same time, the government believed that the state electric company exercised more influence than the regulating agencies charged with its oversight, so that it had become an entity that went its own way, regardless of the public interest. It was also felt that the government's regulatory and business roles, quite generally, were in conflict. Oil, coal, gas, and electricity prices, mostly set by large state companies, were completely distorted. Cross subsidies produced an inefficient use of resources. Unnecessary investments were being made, and capital was being diverted from other social needs.

Under Philippi's leadership, a nationwide energy strategy was formulated. A key element was that decentralized decisions by energy consumers and producers had to yield economic efficiencies. The implication was that prices of different energy products had to reflect their true economic value, so that individual decisions coincided with the least cost for the country. That understanding led first to legal and institutional changes to deregulate prices of liquid and solid fuels.

The question immediately arose as to what to do with electricity. The glaring problem here was that electricity competed with liquid and solid fuels as an alternative energy source, but—unlike coal and oil—had no international reference price. Moreover, the system was primarily hydroelectric, making the determination of market prices all the murkier.

Chile's solution was formulated by Sebastián Bernstein, an engineer with the state company who joined Philippi at the CNE. Bernstein was influenced by the French economic school of thought, which stressed use of market prices in regulated sectors. He considered that an efficient and coherent electricity price policy could be based on the use of marginal supply costs. Thus was born the idea of a competitive electricity market at the generation level, and actions were taken to facilitate the development of such a market.

Even with a strong military government in charge, it was not easy for Philippi and Bernstein to bring forward their proposals. Criticism arose not only in the powerful, vertically integrated state monopolies, but also within the military hierarchy. The country had long been accustomed to believe that energy was a strategic resource and had to be handled by the state so as to guarantee independence from abroad. Price subsidies were considered justified because electricity was an "essential" living expense for the population. Furthermore, in the beginning, international funding agencies were not supportive. The

World Bank still made loans conditional on the use of prices based on rate of return on net fixed assets, rather than on market prices.

But engineers with the state-owned electricity companies were soon convinced of the benefits of the new model and started helping to further develop the proposals. Different problems had to be solved along the way, among them a winter with brown-outs. Decisions often were influenced by specific events and difficulties. It was not a process where a policy was first set and then implemented. Often, uncoordinated solutions had to be chosen, but always with an overall philosophy that gave them coherence. The adjustment of prices for end-users took time, as simulations showed that price would rise a great deal for some customers, while dropping for others. The upshot was the cumulative introduction of price increases to customers over periods of one to two years.

As in any pioneering effort, there was no one to learn from. The changes in the United Kingdom were to start several years later, while the academic proposals on deregulation and spot pricing were to come much later in the United States. But isolated ideas from electric sectors of other countries were adopted — for example, the incorporation of an independent system operator to plan operations for several private generators was founded on Belgian experiments [1].

In a nutshell, up to 1980, electric regulation in Chile followed the usual pattern of contemporary electric systems: state-owned firms that were vertically integrated and subject to rate of return regulation. The operation of electric generation companies (gencos) was inefficient, a consequence of the state not having an independent regulatory agency capable of regulating its own firms and of prices that were set in order to respond to short term political objectives. In 1982, culminating a difficult process, an important electricity law was issued, though it still remained within the framework of a largely state-owned system[1].

The law introduced a revolutionary price system. Electric generation was decentralized and functionally separated from transmission and distribution, and incentive regulation was introduced in distribution. These massive changes in regulatory incentives were supplemented with the creation of a new regulatory agency with a ministerial rank, the CNE, followed by the privatization of the industry in the late eighties.

Today all transmission and distribution is privately held, while the small fraction of generation still in the hands of the state will soon be privatized, too. Yet not long ago the Chilean government controlled 90 % of generation, all transmission, and 80% of distribution.

Chile's regulatory reforms have been quite successful and as a result, the regulatory incentives they introduced became a standard reference for reform in several countries [2]. In Latin America, new electric sector regulations were set in Argentina in1992, Perú in 1993, Bolivia and Colombia in 1994, the Central American countries of Panamá, El Salvador, Guatemala, Nicaragua, Costa Rica and Honduras in 1998 In Europe this process

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1 The key law is the DL N± 1 of 1982. It can be found in http://www.cne.cl

started with the U.K. in 1989, followed by the Scandinavian countries in 1990 – 1995. For the member states of the European Union, a 1996 directive of the European Parliament defined the framework of a common European electricity market and required all member states to introduce competition in the electricity supply sector by February 1999. Reforms in the structure of electricity services in the US started with the California restructuring proposal in 1997 and the Federal Energy Regulatory Commission (FERC) creating open access conditions. Norway in 1987 and Australia in 1991 also created competition condition in the electrical sector. Currently there are a growing number of countries in Asia and East – Europe that will join the worldwide restructuring process [3].

The reforms have had significant results in generation. From two initial power suppliers, there are currently five gencos competing in the main grid. Annual generation more than doubled from 1990 to 1998. There has also been a positive impact on the quality of service. Average response time to electrical outages has shortened markedly. Productivity of utilities increased substantially, including a doubling of labor productivity in distribution, and a tripling of energy generation by worker in the largest genco. Distribution losses, energy theft included, were halved in seven years, diminishing to 8.3 % in 1997. Clearly privatized firms increased their efficiency and coverage substantially.

However, productivity gains have not been passed on to consumers via lower prices in a similar way as in more competitive later generation deregulators in Latin America (Fischer and Serra, 2000, doc 86). In the main market, the regulated wholesale price of electrical energy fell by 37.4%, and technological change stranded (that is, rendered uneconomical) a large fraction of existing thermoelectric plants. In contrast, the final price to customers did not fall to reflect the huge productivity gains that were achieved after privatization. Between 1987 and 1998 the regulated price to consumers fell by only 17%. This situation led to spectacular increases in the profit rates of distribution companies: the rate of return of the largest Disco rose from 10.4% to 35% in this period. These profit rates are striking considering the low risks involved in monopoly distribution.

Chile as a “first mover” reaped the benefits of deregulation and privatization first, but has had more difficulty in adapting its system to the new more competitive trends that in many cases have allowed significant benefits to consumers.

2. CHILE'S ELECTRICAL SYSTEM

2.1 The four interconnected systems

There are four interconnected electric systems in Chile. The Interconnected System of the Norte Grande (SING) covers the area between Arica and Antofagasta with 33% of the country's total installedcapacity. Next is the Central Interconnected System (SIC), which extends from Taltal to Chiloé with 66.2% of the total installed capacity. Thirdly is the Aysen System which supplies Region XI with 0.2% of the total capacity and lastly the Magallanes System for Region XII with 0.6% of the country's total installed capacity..

THE INTERCONNECTED SYSTEM OF THE NORTE GRANDE (SING)

The SING is made up of a combination of central generators and interconnected transmission lines which supply electric power to Chile's Regions I and II. The SING's huge growth potential stems from the many large mining projects in the area. The size of a single project will often justify the incorporation of a whole generating plant. Therefore, the decision to build a plant is subject to concretizing a mining project and vice versa.

Approximately 90% of SING's energy is consumed by large clients, mines and industries, defined by law as clients which are not subject to price regulation. The remaining portion is concentrated in the distribution companies that supply clients who are subject to the price regulations of Regions I and II.

Generation

The SING has an installed capacity of 3,352 MW as of December 2000. The maximum demand reached 1,211 MW in 2000, while the total energy generation in that year was approximately 9,327 GWh.

A total of 6 generating companies operate in the SING that together with a transmission company form the Economic Load Dispatch Center of the SING (CDEC-SING).

As it is a predominantly thermal system, the generating equipment is comprised of units fired by coal, fuel, diesel and as of 1999, by combined-cycle mode natural gas. There are only two hydroelectric units that are located in Chapiquiña and Cavancha.

Transmission and Distribution

The transmission system is primarily made up of electric lines owned by the generation companies, by the clients themselves, and by electric transmission companies.

Three energy distribution companies operate in the SING: EMELARI S.A., which supplies the city of Arica; ELIQSA S.A. which supplies the city of Iquique; and ELECDA S.A., which provides energy for the city of Antofagasta. A part of the SIC also corresponds to Taltal. Altogether these three companies supply a total of 218,553 clients.

THE CENTRAL INTERCONNECTED SYSTEM (SIC)

The SIC is the country's primary electric system, providing electricity to more than 90% of the country's population. The SIC extends from Taltal in the North to the island of Chiloe in the South. The SIC is a hydrothermic system which, as opposed to the SING, primarily supplies clients (60% of the total) subjected to rate regulations.

Generation

The SIC has an installed capacity of 6,646 MW from a total of 20 generation companies that together with some transmission companies form the Economic Load Dispatch Center of the SIC *(CDEC-SIC)*. In 2000, the maximum demand reached 4,576 MW, and the total generation of energy in the same year was approximately 29,577 GWh.

The generating equipment is composed of 60.5% hydraulic plants and 39.5% thermal plants fired by coal, fuel, diesel and combined-cycle natural gas.

Transmission and Distribution

The transmission system is principally composed of electric lines owned by generation companies plus those lines owned by electric transmission companies. There are 31 distribution companies that operate in the SIC altogether supplying a total of 3,658,049 clients.

THE AYSEN SYSTEM

The Aysen System provides for the electricity consumption of the XI Region of Chile and is a 76% thermal system. Its installed capacity reached 17.1 MW (2000). A single company, EDELAYSEN S.A., is responsible for the generation, transmission and distribution of electricity to 18,703 clients. In 2000, the maximum demand reached 13.75 MW, while consumption in the same year was 74.7 GWh.

THE MAGALLANES SYSTEM

The Magallanes System is composed of three electric subsystems: the Punta Arenas, Puerto Natales and Puerto Porvenir Systems in Region XII. The installed capacity of these systems at the end of 2000 was 58.5 MW, 4.2 MW and 1.8 MW, respectively, each system 100% thermal. The maximum demand in year 2000 reached 29.8 MW, 2.8 MW and 1.1 MW, respectively, while energy consumption in the same year was 145.5 GWh, 13.4 GWh, and 4.1 GWh, respectively. Only one company, EDELMAG S.A., is responsible for generation, transmission, and distribution of electric energy in these systems supplying a total of 43,886 clients.

2.2 Evolution of installed capacity and energy production

An explosive growth has occurred throughout the country not only in installed capacity, but also in total electricity generation. The graph below demonstrates how the installed capacity increased from just over 4,000 MW in 1990 to more than 10,000 MW in 2000. This implies an annual growth rate of 10% in the installed capacity during the last decade. In the case of total generation, the country increased from 18,000 GWh to more than 40,000 GWh in 2000, an annual growth rate of 8.5% over the decade.

Figure 1 Installed Capacity by Interconnected System

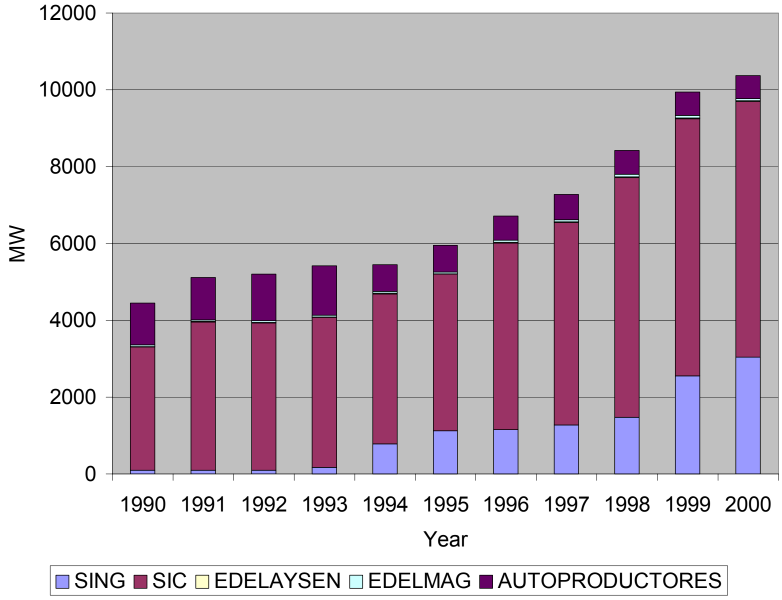
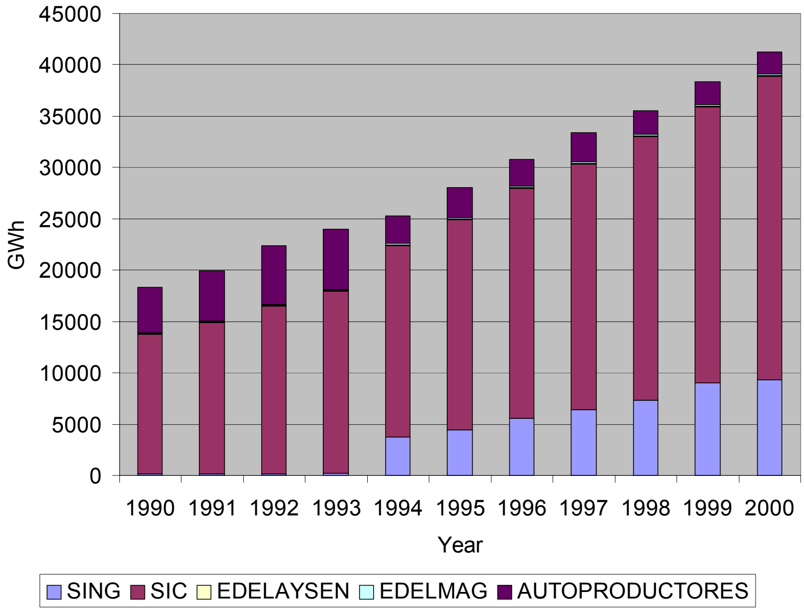


Figure 2 Gross Generation by Interconnected System



Figures 1 and 2 show the evolution in capacity and total generation, respectively, from 1990 to 2000 for the whole country and segmented according to the contribution of each of the four interconnected systems and self–producers. As shown in the previous figures and as previously mentioned, the primary interconnected system is the SIC followed by the SING.

2.3 Evolution of Thermal and Hydroelectric Generation and Related Emissions

Chile's electrical generation is predominantly from hydroelectricity, except in drought years when it must rely on thermal generation. Table 1 presents the extreme variability in generation. In "good years" up to 75% of the total energy can be generated from hydroelectricity, whereas in "bad" years less than 30% is generated by this technology.

Table 1: Percentage of Hydroelectric and Thermoelectric Generation by Year

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
HYDRO	49%	66%	75%	72%	67%	66%	55%	57%	45%	35%	29%
THERMO	51%	34%	25%	28%	33%	34%	45%	43%	55%	65%	71%

The previously discussed process of reform in the energy sector and the establishment of agreements with Argentina to liberalize the trade of natural gas between the two countries in 1997 have brought about an important change in the composition of the Chilean energy matrix. In effect, electricity companies that have incorporated new technologies of generation are primarily the largest users of natural gas, in particular those combined-cycle natural gas plants. They use natural gas which is cleaner than other fuels utilized in thermogeneration,[2] and this change has had environmental implications.

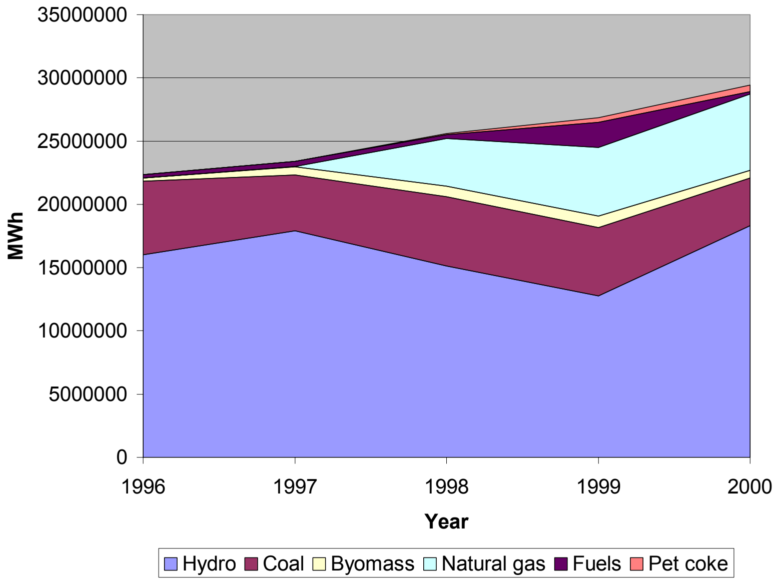
In 1997 the independence of natural gas transport for distribution was established in such a way that the pipelines would operate as "carriers" to transport gas according to the needs of the distribution companies or the large end-users. This produced an atmosphere of competition with respect to pipeline construction to such a degree that in 1999 two pipelines were constructed in the North, even though in economic terms only one was justified. GASATACAMA and NORANDINO, both in Region II, transported gas from Argentina to the combined-cycle mode plants located in the SING, and to mining and industrials centers in the area.

The importation of Argentinean natural gas to central Chile was begun two years earlier in August 1997 through the international GASANDES pipeline transporting it from Cuenca Neuquina to supply the Santiago distribution company and three thermoelectric plants in the SIC. The supply for Region V from the city gates of GASANDES has been through the ELECTROGAS national pipeline since 1998. The Pacific pipeline began transport of natural gas from Cuenca Neuquina to Region VIII in October 1999 principally to supply the

[2] A case study comparing all industry and power generators in Regions II, VII, VII and VIII assuming first they operate with natural gas, and then a mix of coal and pet – coke shows that emissions of particulate matter in the latter case are 7.2 times greater, 10.9 times for sulphur oxides and 6.3 times for nitrogen oxides. [12].

industrial and residential distribution companies. The impact of natural gas' introduction into the energy matrix can be seen in Figure 3.

Figure 3 Energy Produced in the Electrical System by Fuel Type



As of 1997, natural gas has grown in importance as a fuel in thermoelectric generation reaching 54% of total thermal generation in 2000. The importance of coal has diminished from 92% of total thermal generation in 1996 to only 38% in 2000.[3]

Generation through conventional thermoelectric plants produces emissions of gases (carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxide (NOx) among others), and particle contaminants that have a global effect on the environment (the greenhouse effect) and local effects such as acid rain, visibility reduction, corrosion of buildings and equipment. Emissions also have a negative effect on the health of people and animals. These emissions are influenced not only by the growing demand for electricity discussed in the previous section but also by the generation technologies utilized. Figure 4 demonstrates the evolution of CO2 emissions between 1990 and 2000 owing to thermoelectric generation in Chile.

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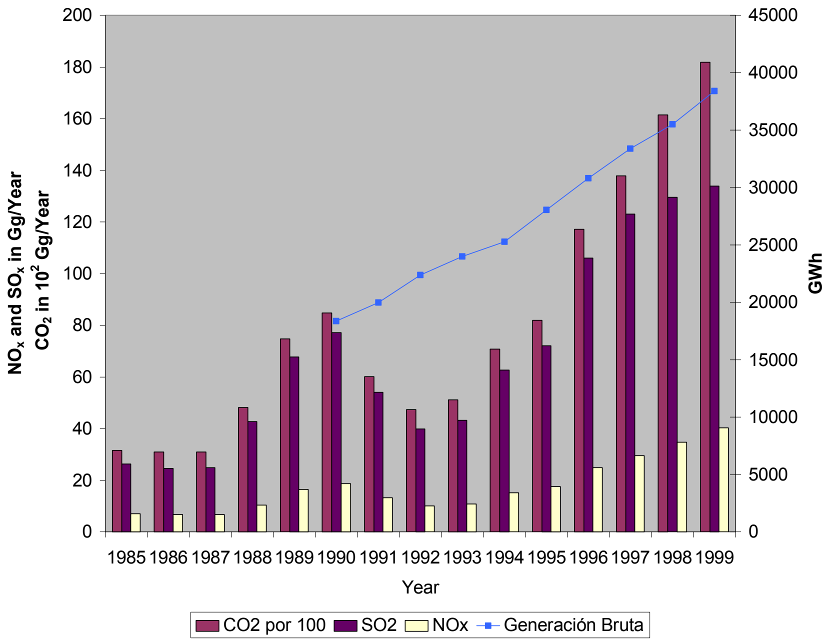
[3] This figure includes petcoke.

Figure 4 Emissions from large combustion plants



A notable decrease in emissions can be observed from 1990 to 1993 and a sustained increase as of 1994. As can be seen in Table 1, these changes are fundamentally a result of the composition of generation: primarily hydroelectric in the years of low emissions and thermal in the years of high emissions. Certainly the increase in total generation is also partly responsible for this increase in emissions as can be seen by comparing 1991 and 1995, years in which there was an equal proportion of hydrogeneration, but a substantially higher emissions in 1995.

3. THE OPERATION OF THE CHILEAN ELECTRICAL MARKET

In this chapter we characterize Chile's electrical market. To begin, it is interesting to note that reform has followed similar paths in most of the countries involved. The common elements of the regulatory frameworks developed for the electric energy sector are:

- Explicit separation of the three businesses (generation, transmission, and distribution) and definition of these vertically disintegrated companies, along with large customers, as the main market players

- Competition at the power generation level, but with all gencos agreeing to be centrally dispatched by an independent operator.

- Licensed operation of transmission and distribution companies.

- No licensing of thermal plants, but licensed construction of hydroelectric plants, which entail the exploitation of natural resources.

- Open-access schemes, where transport concessionaires must permit open and nondiscriminatory use of their transmission systems.

- The assignment to distribution concessionaires of the right and obligation to supply electricity locally in the present and in the future.

- A pricing system in which both generation and transmission business have operational or capacity expansion marginal prices or both. Distribution service is priced on the basis of the marginal cost of expanding capacity, which is evaluated using model distribution companies or price cap schemes (both corresponding to yardstick regulation schemes).

- Penalties applied to stimulate better service: distribution companies are subject to fines for not serving customers, and in some countries transcos also face penalties for not providing service.

However "similar" does not mean "identical." The following table summarizes some major regulatory differences among systems in Latin American countries, that permit characterizing Chile's system.

Table 2: Main Characteristics oc Chile's Electrical System

Issue	Chile	Other Countries
Cross ownership of generation, transmission and distribution	Not defined in the Law, allowed in practice.	Argentina, Bolivia, and Perú put severe restrictions. In particular Argentina and Bolivia bar any generating company from holding more than 10 percent or 30 percent of the market, respectively.
The system operator in charge of coordinating grid operations.	Run only by generators and transmitters.	In Perú the operator includes generators and transmitters, and in Argentina and Bolivia also includes distributors, large consumers, and the regulator.
Power plant dispatch	In Chile, Perú, and Bolivia generation is dispatched on the basis of audited costs.	Bid prices are used in Argentina and Colombia.
Transmission services	Chile has favored the development of several private transmission operators, similar to Argentina.	Perú, Colombia, and Bolivia have left the transmission system under the control of a single nationally owned company.
Distribution	Argentina, Chile, and Perú have chosen the concept of model distribution companies to set distribution rates	Bolivia has opted for the British price cap scheme, where rates are adjusted with inflation plus a yearly efficiency reduction.

Chile's electrical system has some unique features resulting from the fact that it was a "first mover" and its particular economic and institutional setup. Introducing competition in the wholesale contract market was a cornerstone of the Chilean reform, and in fact this is the only free market in the system. This is the market in which gencos and large customers and discos establish long-term supply contracts. Since participants in this market are located in different geographic areas, the unbundling of transmission services was a requisite for wholesale competition. Thus the principle of open access to the transmission network was introduced, and gencos and the transmission company (transco) were allowed to freely negotiate transmission fees. The second major innovation of the Chilean system was that investment in generation was left to market forces. As the expansion of the demand for electricity leads to higher prices, the profitability of developing new projects increases. Existing enterprises or potential entrants will invest in generation whenever a project has a return on capital that is commensurate with the sector's risk.

Although the market for large customers was completely deregulated, retail services remained highly regulated. Distribution companies are required to provide service within their (nonexclusive) franchise areas at a regulated retail price. This price has two components: (1) the regulated price at which discos purchase energy and power from generators and (2) the value added of distribution (VAD), which remunerates services provided by the disco. Using incentive regulation to compute the VAD was Chile's third major regulatory innovation. Prices are set in such a way that, in principle, an efficient disco would attain a predetermined rate of return [4].

We examine each component in more detail in what follows.

3.1Generation

Legislation allows only generators and large buyers to participate in the wholesale market, such that consumers can be divided into large consumers who buy for their own consumption and distribution companies or commercialization firms, which buy in order to sell to small consumers.

Pursuant to the Chilean Electricity Law, enacted in 1982, gencos must coordinate their operations through the pool operators (CDECs) to minimize the operating costs of the electric system. Gencos meet their contractual sales requirements with dispatched electricity, whether produced by them or purchased by them in the spot market.

Gencos balance their contractual obligations with their dispatch by buying electricity at the spot market price which is set hourly by the CDEC, based on the marginal cost of production of the last generation facility dispatched ("spot marginal cost").

The principal purpose of a CDEC in operating the dispatch system is to ensure that only the most efficiently produced electricity reaches consumers. However, the CDEC also seeks to ensure that every genco has enough installed capacity and can produce enough electricity to meet the demand of its customers.

Sales by gencos may be made pursuant to short or long term contracts or, in the case of sales to other generation companies, on a spot basis. Gencos are free to determine whether and with whom to contract, the duration of contracts, and the amount of electricity to be sold.

Under the Chilean Electricity Law and regulations there under, sales to distribution companies for resale to regulated customers (customers with demand for capacity equal to or less than 2 MW) must be made at the nodal prices in effect at the relevant locations or "nodes" on the interconnected system through which such electricity is supplied. Two nodal prices are paid by distribution companies: nodal prices for capacity and nodal prices for energy consumption. Nodal prices for capacity are calculated based on the annual cost of installing a new diesel fuel gas turbine generation facility. Nodal prices for energy are calculated based on the projected short term marginal cost of satisfying the demand for energy at a given point in the interconnected system, quarterly during the succeeding 48 months in the SIC and monthly during the succeeding months in the SING. In order to determine such marginal cost in the SIC, a formula is used that takes into account ten year projections of the principal variables in the cost of energy at each substation in the interconnected system over the 48month period. This includes projected growth in demand; reservoir levels (which are important in determining the availability and price of hydroelectricity); fuel costs for thermal electric generation facilities; planned maintenance schedules or other factors that would affect the availability of existing generation capacity; and scheduled additions to generation capacity during such period. The same general principles are used to determine marginal cost in the SING.

Nodal prices for capacity and energy consumption are established every six months, in April and October, by a decree issued by the Ministry of Economy. Although nodal prices are quoted in Chilean pesos, the calculations used to determine nodal prices are mainly effected in U.S. dollars. Nodal prices so established become effective in May and November. Nodal prices are adjusted during a six-month period only if changes in the underlying variables in the formula used to project a nodal price then in effect would result in a variation in excess of 10%. In addition, the Chilean Electricity Law requires that the difference between nodal prices and the average price paid by unregulated customers in the six-month period prior to the date of nodal price calculation not exceed 10%. If nodal prices do not meet this requirement, they will be adjusted so that such difference will not exceed 10%.

Distribution companies are required to pay generation companies for each month's electricity purchases on the 21st day of the following month, at the applicable nodal prices in effect at the time.

The Chilean Electricity Law provides that if a genco sells directly to a regulated customer, for example when such customer is outside the concession area of a disco , then such genco must apply the same price as the disco would be required to apply[4].

A genco may be required to purchase or sell energy or capacity in the spot market at any time depending upon its contractual requirements in relation to the amount of electricity from such company to be dispatched. Purchases and sales made in the spot market are transacted at the "spot marginal cost" of the interconnected system in which the companies are located, which is the marginal cost of the last generation facility to be dispatched. Generation companies making sales in the spot market are paid for each month's sales on the 22nd day of the following month at the spot marginal cost in effect at the time of sale.

Sales to unregulated customers (customers with demand for capacity of more than 2 MW), whether directly by a genco or through a disco for consumption by such disco's customers, are not regulated and are made at negotiated prices.

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[4] If the Ministry of Economy issues a rationing decree due to prolonged periods of electricity shortages caused by drought or failures of thermal electric facilities, under the Chilean Electricity Law, generation companies may be required to pay to distribution companies or regulated customers an amount equal to the product of (i) the difference between the rationed price specified in the rationing decree and the applicable node price and (ii) the difference between actual energy consumption during the period to which the rationing decrees relates and energy consumption during the same period in the prior year, with certain adjustments.

The problem of getting the prices right

The main advantage of using short-term marginal costs to determine dispatch is that it reduces the possibility of short-term strategic behavior on the part of gencos, which is a real concern for spot markets with bidding and few participants. The danger of noncompetitive behavior would be high in Chile, which has few gencos. On the downside, the use of marginal costs requires that pool operators play a prominent role in determining short-term marginal costs, especially in systems with an important hydroelectric component. The determination of the marginal cost thus becomes a major source of disputes among the gencos within the pool and between the gencos and the regulator[5]. It also becomes attractive for gencos to lobby the regulator that oversees the pool operator to bend the rules in their favor. Disputes may arise over the relevant components of the marginal cost and over the price of inputs used to generate electricity. For instance, determining the appropriate price of an input such as coal or allowing the use of environmentally polluting sources of energy may become major issues, as they can alter the order of dispatch.

It was expected that high energy prices would give incentives for more investment in generation. This actually happened, and up to 1999 investments have been made ahead of the indicative plans prepared by the government. However Chile has suffered supply problems in extremely dry years basically due to regulatory failures, particularly enforcing outage cost payments.

Countries like Chile where hydroelectricity is the main source of power face a major difficulty in price smoothing, namely, how to reconcile the inherent variability in energy availability with an unresponsive demand induced by the fixed regulated price. If an energy shortage occurs during a drought, regulated consumers are entitled to receive compensation for reductions in consumption below their normal level at around four times the normal cost of energy. This is called the outage cost, and it is usually calculated as the cost to users of an anticipated energy shortage (as opposed to an unexpected power shortage).

In principle, these compensations create the correct incentives for consumers and generating firms. However, the magnitude of the compensations in relation to the normal price of energy creates enormous incentives to haggle over the fulfillment of the conditions under which compensations are paid, since gencos with energy deficits are understandably unwilling to pay. In fact, gencos have never paid compensations in Chile during periods of restricted supply (namely, 1989–90 and, more recently, 1998–99). The lack of forces driving the market to equilibrium resulted in random outages, which imposed a large cost on society. More flexibility by the regulator would have solved the problem by raising prices in order to reflect the changed availability of energy.

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[5] For instance, gencos often question which costs are variable in the short run and should thus be included in the marginal cost determination of the regulated energy price. In Chile in early 1999, a genco signed a long-term contract with a gas pipeline which set the transport price and a floor on the transport volume the company was required to pay. Should the fixed part of the transport cost be considered a fixed or a variable cost? Similarly, consider the case of a vertically owned specialist port for coal, whose main use is to unload coal to its upstream owner. Should the capital costs of the port be considered part of fixedcosts?

Lack of Competition in Generation

An important problem in Chile (and other several Latin American countries) is the lack of competition in power generation. In Chile’s main interconnected system the SIC, the Herfindahl index reaches 5800, with only three major participants. In effect, the largest genco and its affiliates own 56 percent of installed capacity. Two other gencos control an additional 37% of installed capacity. To complicate things further, the holding of the largest genco owns the largest electricity disco, which serves more than 50 percent of the demand of regulated consumers (these computations include Rio Maipo, an affiliate). The same company owns more than 70 percent of the remaining water rights that could potentially be used to generate electricity.

This market dominance, coupled with the complexity of the electric utility legislation, has effectively limited entry into the market since privatization. Potential entrants are afraid of confronting this behemoth, given the possibility of discrimination within the pool, the lobbying power of the dominant firms, the problems in legislation, the possibility of discretion by the regulator, and the inefficiency of the judicial system for companies seeking redress.

The formation of one dominant company, that up to less than a year ago also owned the main transco, was a result of Chile's privatization process as well as posterior regulatory decisions, when the company was allowed to buy an additional plant that was being privatized. This is currently perceived as a mistake that limited further competition in the wholesale market.

3.2Transmission

Chile has, by far, the least-regulated transmission in the region. Although the legislation and the regulating agency set some guidelines, transmission fees are directly negotiated between the transco and each genco. To the extent that a company's transmission assets were constructed pursuant to concessions granted by the Chilean government, the Chilean Electricity Law requires such company to operate the covered transmission system on an "open access" basis in which new users may obtain access to the system by participating in the investment to expand the system.

Transcos recover their investment in transmission assets through tolls, or "wheeling rates," which are charged to gencos. The toll is calculated according to a formula pursuant to which the owner of the transmission lines is reimbursed for its investment and operating costs relating to the transmission lines used. The amount of the toll (or the specific components of the formula) may be negotiated between the transco and the genco. Disputes relating to transmission matters are submitted to an arbitration proceeding in accordance with the Chilean Electricity Law.

Transmission franchises are subject to free access rules, but they are not required to build new lines, and new franchised lines are not evaluated by the regulator. All users share the cost of lines, so they could be required to pay for undesired investments that provide benefits for other users. Moreover, since it is difficult for parties to agree on the efficient transmission system required, there is an incentive to over invest. In partial mitigation, the regulator does provide a ten-year investment plan for generation and transmission that minimizes the present-value costs of investing in, operating and rationing the system. This plan is only indicative, but it could be used in legal arbitration.

Negotiations between the Chilean gencos and transcos have never been successful, always leading to arbitration. The outcome of arbitration is not predictable, because the rulings do not create jurisprudence.

An example of a unsuccessful negotiation was that of Colbun, an independent genco. The genco eventually built a line that runs parallel to the main transmission line after being unable to reach an agreement with the transco. Building a new line was an inefficient option, but the genco preferred the independence gained through owning its line to negotiating with the transco, at that time owned by a rival. These difficulties have created uncertainty in the development of the generating sector, which appears to have foreclosed new entry into the sector.

In June 1997, the Chilean Antitrust Commission ruled that within a “prudent” period, the main genco's transmission subsidiary should become an independent joint-stock company operating exclusively in the transmission segment, thereby opening up the company for other parties to participate in ownership. The main genco eventually sold the transco to Hydro Quebec at the end of 2000.

In 1998, the Chilean transmission regulation was modified to correct some of the problems that had been observed. The regulator has a saying in determining transmission usage by gencos, whereas before it was negotiated. There is some scope for regulatory discretion, but this seems to be a minor problem in comparison to the previous situation. Most recently, the NEC has announced that the transmission regulation will be simplified, with the regulator defining transmission payments, that would be shared 50% by gencos and 50% by consumers, while at present gencos pay the total.

3.3 Distribution

Chile was the first country to explicitly introduce incentive regulation. The 1982 legislation defines rate-setting schemes based on marginal cost pricing in simulated efficient enterprises. Distribution companies are awarded franchises that obligate the disco to provide service throughout the franchised area. The discos buy electricity for their clients and pass on the purchase price. The tariff charged by distribution companies to their regulated customers is determined by the sum of the purchase cost incurred by the disco(the nodal prices for capacity and energy consumption at the point of purchase from the genco) and the value added by the distribution network (the "VAD").

The VAD includes operating costs, allowed energy losses and a return on investment and is recalculated every four years for a model or efficient firm supplying similar types and locations of customers. The rates provide a 10 percent real return on the replacement value of assets. These rates are then applied to existing companies. If the actual average industry return on the replacement value of assets exceeds 14 percent or falls below 6 percent, rates are adjusted to the nearest bound. The hypothetical efficient firm is built on the basis of the real firm that the regulators believe to be the most efficient among existing firms, introducing an elementary type of yardstick competition.

The privatization of distribution companies led to substantial new investments and efficiency improvements in Chile. The largest disco more than doubled its sales from 1987 to 1997. It also managed to cut energy losses from 19.8 percent to 8.3 percent and to raise the number of clients per worker from 376 to 703 in the same period. The service expansion is explained by the relaxation of financial constraints faced by public enterprises, combined with a comparatively stable, impartial regime of contract law for privatized utilities. Private-sector managerial capacity explains the gains in labor productivity. The isolation of public services from political pressures has also helped to improve performance indicators: before privatization, political meddling made it almost impossible for state-owned companies to dismiss low performance workers, especially if they had political backing. Finally, the new regulatory system encourages efficiency.

Despite these gains, however , the prices of regulated services have not fallen to reflect the huge productivity gains that have been achieved since privatization. Between April 1987 and April 1997 the all-inclusive tariff paid by consumers in the central (and most densely populated) zone in Chile fell by 11.4 percent in constant dollars, although the generation price fell by 37.4 percent, energy losses were reduced substantially, and labor productivity increased significantly in the same period. It also became easier to stop service to customers who did not pay their bills and to penalize those who pilfer services. Consequently, the rate of return of distribution companies rose significantly. For instance, the largest disco (serving almost 40 percent of the population) saw its rate of return increase from 10.4 percent in 1988 to 35 percent in 1997. The profitability of other discos followed a similar trend. Such rates are way above those being earned by gencos, even though gencos are subject to far greater uncertainty since they do not have a captive market and they face hydrological variations.

It seems that problems inherent to incentive regulation have prevented distribution efficiency gains from being fully passed on to consumers.

3.4 Regulatory Governance

In this section we describe the institutions that regulate the electricity sector in Chile. There are four institutions that oversee the workings of the electricity market: the National Energy Commission (CNE), the Ministry of Economics, the Superintendency of Electricity and Fuels (henceforth SEC, its Spanish acronym) and the Economic Load Dispatch Center (henceforth CDEC, its Spanish acronym), the pool operator. We describe the role of each in turn.

The CNE

The CNE advises the government on energy policy. The head of the CNE has ministerial rank, but, somewhat inconsistently, the CNE is governed by a board that includes 5 additional ministers. This board reports directly to the President of the country. An executive secretariat is in charge of operations. The CNE studies and proposes regulations, calculates regulated prices, provides technical advice to the government and is in charge of the technical oversight of the sector. Regulatory rule changes are usually prepared by the CNE. It is important to note that CNE regulates and advises the government, but it has no power to enforce compliance. The CNE also elaborates an indicative expansion plan for the country's two large electrical systems.

The CDEC

The pool regulator coordinates the operation of the generation-transmission system in central Chile and is responsible for system security. The CDEC must inform gencos of current demand and supply conditions, coordinate power plant maintenance and verify compliance with the system's operational rules. Finally, the CDEC determines the spot price at which transfers of energy and power between gencos are valued.

CDEC includes only power gencos with more than 2% of the installed capacity and transcos with at least 100 km of transmission lines.

The 1982 electric law and its 1985 statute left the internal operations of the CDEC somewhat undetermined, but this was corrected with a bylaw in 1998. Before 1999, the CDEC was composed by a board, an operations directorate and several working groups organized by area. The board governed the institution. Each member had one vote and the presidency rotated among all members. The pool operation was managed by an operations directorate which included a representative of each company. It was responsible for coordinating dispatch, verify the calculations and studies elaborated by the different working groups and ratify each month the balance of physical and pecuniary transfers between gencos made by the respective working groups.

An important weakness was that disputes within the operations directorate had to be referred to the board, which could only settle them by consensus. If the board was unable to reach the required consensus, the Ministry of Economics was responsible for issuing a decision within 120 days. This implied that unsettled issues could linger for a long time, and in the meantime decisions taken by the operations directorate on these issues were not legally binding on the companies.

The independence of the CDEC increased after the companies implemented in June 1999 the changes that had been introduced in the 1998 bylaw which mandated an independent CDEC. While it is still governed by a board of company representatives, its operations are delegated to independent personnel. The procedures and models required to operate the system and model parameters are set by the independent operations directorate. A board member who disagrees with a decision made by the operations directorate can ask the board for a review. As before, the board needs a consensus to settle disputes, but if no unanimous decision is reached, the conflict is referred to an expert committee, which has 30 days to issue an opinion. If the decision is still not accepted unanimously by the board, it is referred to the Ministry of Economics, who has 60 days to settle the conflict. The most important change, however, is that the decision of the operations directorate is legally binding while a verdict is pending.

The Ministry of Economics

The Ministry of Economics is responsible for setting tariffs following the proposals of the CNE. In addition, it has two functions that are of particular importance during a supply restriction. First, as indicated before, it must settle the disputes between gencos that emerge in the CDEC. Second, it is in charge of issuing rationing decrees. In both cases the law forces the Minister to ask for a technical report from CNE.

The SEC

The SEC is an independent supervisory agency that reports directly to the President. It is responsible for monitoring compliance with the law and its regulations. Among its duties are verifying compliance with service quality standards and investigating the causes of outages. Until recently the fines that it could impose for noncompliance were very low: the maximum fine was about US$ 26,000. Changes introduced in June 1999 increased the maximum fine to about US$ 6 million. Moreover, the decisions of the SEC were usually delayed by companies´ appeals in court. The legislative changes introduced in June 1999 raised fines and determined that before going to court, the firm had to post 25% of the fine.

Other institutions that relate to the electricity sector, as required by other laws, are the Chilean Environmental Commission (CONAMA), the Antitrust Commission and the Municipalities.

4. REGULATORY FRAMEWORKS THAT AFFECT THE ENVIRONMENTAL IMPACT OF THE ELECTRICAL SECTOR

4.1 Electrical Law and the Environment

Two relevant issues with potentially high environmental impacts, investment in new power plants, including plant location and tecchnology, and power plant dispatch are not treated in the electrical law fron an environmental perspective.

Even though in Chile there is full freedom for investment in the electrical sector, there exists a minimal degree of coordination for generation investment. The CNE accomplishes this, through the elaboration of an indicative expansion plan for the country's electrical systems. The electrical law requires that every six months the CNE must determine nodal prices for energy and capacity based, among other factors, on a regular update of the indicative plan. The reason for this is that these prices must correspond to a long-term projection (4 years) of the generation transmission marginal costs. The criterion used in the indicative planning consists of determining those options and project sequences, usually proposed by private investors, that minimize the costs of investment, operation and non-served energy over a time horizon.

In principal than, authorities can influence the type, timing and location of new power plants. More so, since financial entities consider favorable that the projects be included in the indicative plan. This would allow in theory incorporating environmental considerations in the planning process. In practice however, social and private evaluations diverge and increasingly the indicative plan is following private decisions rather than vice versa.

In effect, private investors are developing projects that, with the tariffs and costs perceived, produce a desired rate of return and also respond to their strategic interests. These interests are different from those of the authority that bases the indicative plan on a social appraisal of fuel costs, investments and return rates. These differences became extremely apparent in 1999 with the construction of the two natural gas pilelines from Argentina in the northern system SING, basically due to competition by two international economic groups that aimed to be strong in the electricity wholesale market with natural gas combined cycle plants, discussed in section 2.1.

The incorporation of natural gas combined cycle plants in the SIC and the SING, mainly due to their low operating costs, have implied the dismissal of coal projects and even capital intensive hydroelectric projects. Most electrical companies are also involved in the natural gas market, so their investment decisions actually consider optimizing in both markets simultaneously. Additionally, the possibility of national interconnections (between the SIC and SING) and even international connections were being considered by private investors, before they were included in the indicative plans. Increasingly, the indicative plan is not associated with an optimum system expansion.

The main consequence from an environmental perspective is that the authorities do not have the possibility of influencing the location or technology of power plants.

A second important provision in the electrical law that affects the environment is that the order in which power plants are dispatched depends on the marginal cost. As will be discussed in the next section, new power plants are required to undertake environmental impact assessments and incorporate environmental controls, whereas older plants do not. As a result more polluting older sources are dispatched first if they have lower marginal costs. For example, using pet-coke in similar environmental conditions as natural gas in power plants would require including in its marginal costs the higher energy consumption in crushing, adjustments to the electrostatic precipitators, sulfur abatement systems, storage and manipulation of pet-coke in closed quarters, among other provisions. Since this is not required, this more polluting fuel may have lower marginal costs than a natural gas plant.

4.2 Environmental Law and EIA

The Chilean Constitution of 1980 grants all citizens the right to live in an environment free of pollution. It further provides that other constitutional rights may be limited in order to protect the environment. Although environmental regulation is not as well developed in Chile as in the United States and certain other countries, Chile has numerous laws, regulations, decrees and municipal ordinances that may raise environmental considerations. Among them is Ley Sobre Neutralización de los Residuos Provenientes de Establecimientos Industriales (Law No. 3,133, of 1916), which regulates the discharge of liquid industrial wastes, and the Sanitary Code which contains provisions relating to waste disposal, the establishment of industries in areas in which they may affect public health and the protection of water destined for human consumption. Bylaws under Law No. 3,133 were published on February 23, 1993. The bylaws provide provide that no industrial establishment may dispose of substances that may pose a risk to irrigation or consumption in any sewer or natural or artificial body of water without prior authorization from the Ministry of Public Works and a favorable determination from the Office of Sanitary Services. The bylaws also mandate governmental approval of any systems that an industrial establishment proposes to use for the purpose of neutralizing or purifying liquid industrial residues.

The electricity companies' operations in Chile are also subject to the Ley Num. 19,300 (the Chilean Environmental Law) which was enacted in 1994. The Chilean Environmental Law requires the companies to conduct environmental impact studies of any future projects or activities that may affect the environment and the review of such studies by CONAMA. It also requires an evaluation of environmental impact by the Chilean government and authorizes the relevant ministries to establish emission standards.

The System of Environmental Impact Evaluation (SEIA) is the vehicle which allows the environmental dimension to be introduced into the design and execution of projects or activities realized in Chile. This system attempts to insure that initiatives in the public and private sector be environmentally sustainable and to certify that they comply with environmental regulations that may be applicable.

Chile's Environmental-framework law (LBMA) and the Regulations of the SEIA of CONAMA (Decreto Supremo Nº30/98) establish that investment projects in Chile must be evaluated prior to their execution. Various categories of projects are defined that must be evaluated. The projects in the electrical sector that must be submitted to the SEIA according to article 10 of the LBMA include:

- high voltage transmission lines and their substations
- generation plants larger than 3 MW

In the years in which the system has been applied approximately 3,600 projects and activities have been submitted for environmental certification. In this context from 1995 to 2001[6], 150 projects related to the electrical sector, in the areas of generation and transmission, have been presented for review. Table 3 shows the details of electrical sector projects submitted from 1995 to date.

Table 3 Electrical sector projects submitted to the SEIA.

Category	1995	1996	1997	1998	1999	2000	2001	Total
b.- High voltage electric transmission lines and substations	0	0	1	1	0	3	7	12
b.1.- Electric transmission lines	4	4	8	23	11	10	5	65
b.2.- Substations	0	0	0	0	5	14	3	22
c.- Energy generating plants larger than 3 MW	5	9	4	6	16	8	4	52
TOTAL	**9**	**13**	**13**	**30**	**32**	**35**	**19**	**151**

Source: information available from www.conama.cl

As can be seen in the previous table, the generating plants represent a third of the projects presented to date. The environmental concern surrounding these electrical sector projects is primarily oriented towards the impact of the first phase of hydroelectric plant construction and in the case of thermoelectric plants in both the construction phase and the operation phase because of the emissions that the process generates.

6 Information as of August 2001.

5. ESSENTIAL ISSUES THAT LINK THE ENVIRONMENT AND THE DEREGULATED ELECTRICAL SECTOR

As indicated before, there are no direct links between the environmental law and the electrical sector regulations. This has resulted in various conflicts demonstrating the need for an integrated solution, where environmental and social costs are considered in the development and operation of the electrical sector. To illustrate the above, several examples of specific conflicts are explained and the key issues and challenges identified.

5.1 Development of the generation infrastructure

5.1.1. Plant technology

The development of the electric generation infrastructure is nowadays driven essentially by market forces. Investors seek alternatives that give them advantages over competitors and/or assure enough revenues. Thus, decisions such as generation technologies and plant sites are decided basically on costs and revenues. Today's Chilean electric energy market is essentially centered in two technologies for new plants: combined cycle natural gas plants and hydroelectric plants.

Given the abundance of natural gas being transported from Argentina and the efficiencies being attained by combined cycle plants, the latter do not have any competing thermal technology. Projections indicate that, other than a 570 MW hydro plant being commissioned in 2003, the future development is based on combined cycles. There are already three plants operating in the SIC and five in the SING. Eight more 370 MW-like plants are foreseen for the next ten years in the SIC.

Combined cycle technology is environmentally friendly, if compared to coal or oil plants previously used in the country. However, in the near term they have displaced potentially cleaner hydro plants and, depending on their location, may cause environmental damage.

5.1.2. Thermal plant location

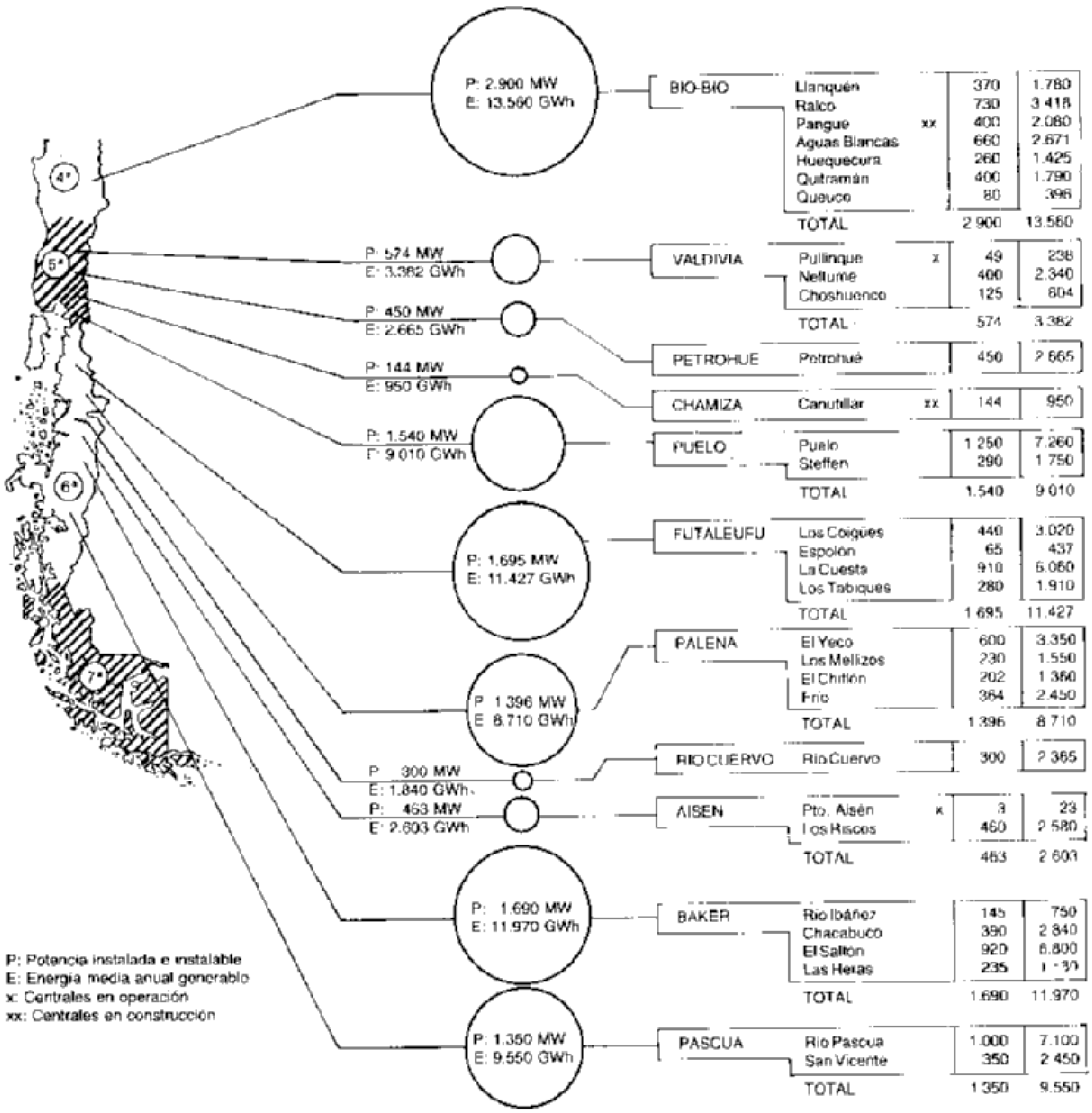
Plant locations are defined based on costs, particularly near existing gas pipes or using low cost extensions. Given that new combined cycle plants in Santiago are out of the question with the city's current pollution problems, sites around the metropolitan area are being sought. Two combined cycle plants are already in operation in the Quillota area and owners of those have already indicated their plans to expand them and build new ones. That area corresponds to a fertile agricultural area and complaints by the community have already been raised. The companies indicate that new plants would still result in emissions lower than authorized levels.

Additionally, possible synergies are missed, for example if a power plant could be built close to Temuco, a city in the south of Chile, than this would allow piping gas to that city economically for household and industrial use. The availability of gas would allow substituting wood burning appliances that are highly polluting, by gas appliances that are cleaner.

5.1.3. Hydro plant development

While hydro plants have lost advantages over combined-cycle plants, there are still important unexploited resources in the country (Figure 5). However, these resources are located either in indigenous populated areas, in regions with a high tourist potential or in unexploited natural forest reserves.

Figure 5



An area of conflict that has arisen over the last years is the development of hydro resources in populated areas, particularly where there is an indigenous population. The Ralco development is a good example. This plant is one of several plants that could be built in the high Bio Bio basin, the basin with the highest energy potential in the country (only Pangue is in operation, a 467 MW plant, with the potential in the basin being 2900 MW). Ralco, a 570 MW plant to be commissioned in 2003, has faced important opposition, led by environmentalists that have questioned its environmental impact and its social impact on Pehuenche communities living in the area.

The Ministry of Economy, advised by the SEC, needs to grant definitive concessions for the construction of a hydro plant and the building of the associated transmission lines (the building of thermal plants does not require concessions under the electricity law). The hydro plant must own the required water rights for the project, water rights that are granted by the General Water Authority, a part of the Ministry of Public Works. CONAMA needs to grant the plant an authorization that it meets environmental restrictions, with an impact study to be submitted by the plant owners. In indigenous lands, other regulations intervene. Articles of the Indigenous Law prohibit forcing inhabitants to sell their land.

The Ralco project was complicated by all these factors. Strong opposition by environmental groups developed, even supported by international groups (such as International Rivers Network). CONAMA initially did not accept the Environmental Impact Study submitted by Endesa, but a new study was presented and accepted. Although not directly involved in the concession process, the CONADI (Corporación Nacional de Desarrollo Indígena) rejected the building of the plant. This occurred because, although most Pehuenche families living in the Ralco area agreed to transfer their lands to the owners and accepted to be relocated elsewhere, a few families refused to transfer. Even the Contraloría General de la República and the Courts intervened. Furthermore, the World Bank also intervened, as its IFC branch complained to the Chilean government that there were environmental requirements agreed to under a financing package, that were not being fulfilled by the Pangue and Ralco plants.

The discussion developed not only in legalistic or social terms, as parties involved developed technical and economic studies to demonstrate that the Ralco plant was or was not the best solution for electric energy supply in the country. However, differences arose on how to quantitatively measure the environmental impact, as regulations in place do not provide for a method to quantify it.

It is important to highlight that the energy regulatory agency (CNE) had no tools to intervene, other than giving its blessing, or not, to the plant when defining the indicative plant. But, as indicated before, the spirit of the deregulation law is that the private sector decides. Therefore, CNE automatically includes in the indicative plan any plant being built and/or informed by the private investors.

5.1.4. Thermal plant fuels

With the arrival of natural gas and combined cycle plants to the Chilean electrical market, plants that burned coal were soon out of business, some of them built only recently. Celta S.A. has a 158 MW coal plant in the SING that was just put in service in 1999 and Edelnor has two similar plants commissioned in 1995 and 1998. Investors owning those plants and others looked for alternatives to overcome these losses.

Therefore, alternative fuels were assessed, and petcoke, a byproduct of the oil industry that is less expensive than coal, arose as a cheap alternative that could compete with natural gas. Petcoke (petroleum coke) is the waste produced from oil refining, a sort of sediment with little combustion capacity and a high content of contaminants.

Edelnor asked CONAMA to approve an environmental impact statement regarding the use of this new fuel. Gener also asked for permission for a petcoke-fired plant in the Huasco Valley, within the SIC system.

The requests are being assessed, with protests from farmers and environmentalists that this fuel would be harmful for people and for the agricultural sector. Lobbying from all parties involved is strong, and foreign investors, who see their revenues limited if petcoke is not authorized, are pressuring the government. One company may go bankrupt if the fuel is permitted.

5.1.5. System operation

The CDEC in charge of each system has the obligation, by law, to operate the electrical system with two objectives in mind: insure secure operation and minimize total costs. Only variable costs are to be considered in the operation models being used for dispatch by each CDEC, but no modeling is presently made of environmental costs. By law, only if emission control variable costs were incurred by any generator, they should be included in the operation models used by CDECs. For example, if the disputed petcoke were to be used, only fuel costs would be included, unless the environmental regulations required that those plants incorporated equipment that would increase plant variable costs.

A friendlier emission control electricity regulation could incorporate environmental costs in system operation, even taking into account the different plant locations to dispatch them. A plant located in a highly contaminated area could reduce its generation, favoring loading plants in cleaner areas. Whatever environmental costs are added to present fuel costs, it would necessarily imply an increase of electric energy prices, affecting final consumers. It would also impact revenues of the more polluting plants. Nevertheless, simulations of the SIC demonstrate that a more significant reduction of the impact to the environment of different generation technologies takes place when investment costs of emission control are taken into account when deciding investment, than when just considering variable costs in dispatch [7].

5.2. Efficient Energy Use and the Electric Sector

Although it is of social interest to make efficient use of energy, current electricity legislation does not stimulate efficient use. Rather, legislation centers on the creation of wholesale competitive markets, which would reduce energy costs. Even though the message of fuel source pricing should orient the consumer towards more economic forms of energy and the cost of energy consumption should stimulate consumers to optimize their usage, this in practice does not occur. There are neither studies which might measure the lesser environmental impact that more efficient energy usage would have, nor regulations that would relate efficient usage with environmental impact.

The electric companies and particularly the distributors that serve end-users, maximize their profit through greater consumption. The distributors, given the pass-through tariff scheme, have an incentive to make the greatest use of their installations, and this occurs with greater consumption. Consequently, efficient-use programs are not attractive, nor are programs of load management (that seek to reduce the peaks in the system.)

Initiatives in this area have been concentrated in the Comisión Nacional de Energía (CNE), which directs the National Program of Efficient Energy Usage. Since 1992, this program has been developing the conditions and mechanisms necessary to promote energy efficiency in different consumer sectors, pushing forward specific programs and legal iniciatives that would facilitate the introduction of new efficient technologies and the implementation of improvements in energy efficiency. Among these activities, this agency has:

- Developed programs for technical assistance and technology transfer to promote efficient energy use

- Attempted to identify and eliminate barriers that today impede investment and projects in the area of energy efficiency.

- Prioritized the contributions of international cooperation that the energy sector recieves for projects and programs related to rational energy use.

- Supported and promoted the creation and distribution of information systems, which make the public more sensitive to efficient energy usage.

A clear assessment of these efforts as well as of private initiatives is not available.

Today the CNE has four main action lines in this area. It seeks to strengthen initiatives related to creating energy efficiency studies at the industrial level. It looks for mechanisms that would permit energy efficiency standards to be integrated into sector regulations (an example is the attempt to produce construction standards that would minimize energy losses from problems of isolated homes). It also seeks to incorporate a separate clause on energy efficiency in the framework of the mining industry’s agreements on clean production and finally, the design of methodologies to assess the efficiency of household appliances.

5.3.-New Trends in Generation

Chile is a country with limited conventional energy resources, outside of its great hydroelectric potential. It does not have attractive reserves of petroleum, coal or natural gas in terms of volume or costs. Thus it has become an net importer of energy, primarily petroleum. With the recent energy connections with Argentina and the future potential with Bolivia and Peru, this dependency is notably oriented towards the use of natural gas as a central component in the energy matrix.

As long as the South American natural gas market does not present saturation in the medium term because of the abundance of resources in Argentina and Bolivia, and rate hikes are not seen, in spite of Brazil's large demand, Chile will probably continue to depend on this resource for a long time to come. In the long run, nevertheless, it will be necessary to explore various pathways of development and these could change the environmental impact of electricity generation.

Nuclear Energy

It could be argued that Chile will require the development of a nuclear plant by the year 2020 for the following reasons:

- The energy demands will be sufficiently large to insert a nuclear plant that will contribute 600 MW

- The hydroelectric resources with economical potential will be used in such a way that it will be necessary to incorporate new thermal plants. In this context, the nuclear-electric option is a competitive alternative when facing high prices in natural gas.

- The reduction in installation costs of nuclear plants, on account of technological advances, will make this option more and more profitable so that they could be competitive in power generation.

- This type of plant will permit Chile to diversify their energy sources in such a way that it could diminish the dependency on fossil fuels with high price volatility.

- The high contamination indexes will force the issue of searching for cleaner alternatives to thermoelectric power generation, especially in regions such as the metropolitan area where there are already critical levels of pollution. The nuclear option presents important advantages in terms of gas emissions and particle contaminants when compared to thermal plants.

These advantages must, however, be assessed with the obvious environmental risks posed by the use, and particularly, disposition of nuclear wastes. In the long term, issues relating to the closure of nuclear sites must also be taken into account. These issues will most probably be even harder to include in legislation and practice than the current environmental issues related to hydroplant development.

Clean Energy

Renewable energy sources, besides conventional hydroelectric power, that have a potential for development in Chile, include:

- Wind power
- Solar energy
- Non-conventional hydropower
- Biomass energy
- Geothermal energy

The CNE (Comisión Nacional de Energía) has carried out diverse but sporadic and usually underfinanced initiatives, to promote the use of these renewable energies. These types of energy sources do not have the environmental impact of emissions of the conventional thermal plants, nor the social impact of the large hydroelectric plants. Given the current private costs, however, these sources cannot compete with conventional energy sources and they are only applicable in isolated, rural areas. Soon these initiatives will be inserted into the framework of the Rural Electrification Program of the CNE.

In the northern part of the country, where there are the highest levels of radiation in the world, there are especially favorable conditions for the use of solar energy. In spite of this, this non-contaminating source of power has not received much attention.

Geothermal energy also has an important area for application that is facilitated by the recent publication in January 2000 of Law Nº 19.657 about Concessionaires of Geothermal Energy, which established a framework to regulate and promote private participation in the exploration and use of geothermal energy.

The CNE in conjunction with The United Nations Program for Development (PNUD), implemented a pilot program to generate electricity for rural zones, starting with the gasification of biomass.

Chile presents favorable geographic and climactic conditions to take advantage of non-conventional hydropower (mini and micro hydroelectric and hydro-load plants in isolated areas. Approximately 110 installations of this type are registered in the country, destined principally for the electrification of homes and telecommunications.

Embedded Generation or Distributed Generation

Recent technological advances and new regulatory structures of the electric sector have created worldwide interest in sources of small-scale electricity generation, dispersed in the distribution network. Distributed generation is defined as generation that has the following characteristics:

- Not centrally planned
- Not centrally dispatched nor predispatched
- Generally connected to the distribution network
- Modular installed potential from kilowatts to tens of megawatts

These distributed distribution systems, could provide reliable energy supply services, with cost efficiency and in many cases removing the need for huge investments in generation, transmission or distribution.

These sources include a portfolio of technologies, not only in generation but also in demand. They could be located nearer the consumer, increasing the possibility for local control and better utilization of dissipated energy, principally thermal, to improve the efficiency of the process and reduce emissions. Distributed generation presents opportunities for important savings through lower costs of energy production, lower levels of investment in the transmission and distribution sectors, improvements in the reliability of the supply in the system in general and improvements in reliability for certain consumers in particular.

Nevertheless there is a lack of explicit regulation to include distributed generation. Under these conditions, distributed generation must comply with the regulations set out for the huge generation plants. Even though in Chile distributed generation does not have great importance in the overall picture, the challenge is how to restructure the wholesale electric energy markets and the associated regulations to permit its future participation and eliminate technical, economic, and regulatory barriers.

6 CONCLUSIONS

Chile's pioneering efforts in deregulating the electrical sector gives valuable elements to understand the way in which a competitive and private electric market can impact the environment *vis à vis* a more regulated market. It also illustrates how regulations can influence –or not- better environmental stewardship by private and public agents.

A first important fact is that Chile's electrical system has expanded very strongly in response to the high economic growth rates of the decade and emissions of all gases is increasing significantly. This trend in growth is expected to continue, consequently emissions will continue increasing unless thermal plants are replaced by less polluting sources such as hydroelectric power plants, or more radical nuclear sources.

Additionally, a strong push in energy efficiency may help. However the policies applied in this line of action have been relatively weak, despite studies that suggest that benefits could be obtained. Gencos and discos do not have incentives in this direction. Clean energies and distributed sources can also help to reduce emissions but are not expected to be significant, despite the important availability of solar power in Chile's north.

Actually the trend in this deregulated sector seems to be going in a different direction. Natural gas combined cycle plants have actually displaced some hydroelectric plants, due to the high investment costs of the latter and increasing hassle to obtain permission to build them under the provisions of the EIA regulation. Additionally, public pressure is mounting against the social impacts of hydroelectric plants –case in hand Ralco-, making it more time consuming to get the projects approved. Nuclear energy can be expected to cause even greater rejection. Electric generation companies on the other hand, have interest in developing the gas sector in which they also have an important participation, so they maximize combined profits!

As a result, decisions are being taken on the generating technology, without due consideration of social costs. In location of the power plants, the most important factor considered is proximity to an urban location which allows using the pipeline to feed industry and households. Large cities such as Santiago and Concepción are being favored. Other smaller cities like Temuco that could obtain important advantages from a gas pipeline are not of interest to current generators.

The environmental stakes of this trend are still out however, since these natural gas fueled power plants have allowed financing new gas pipelines that also feed the industrial and domestic sectors. Natural gas is a cleaner fuel than normally used in these sectors, so a reduction in emissions is already being observed, particularly in Santiago's industrial sector. Additionally, natural gas plants have weeded out more polluting coal plants.

In the shorter run, other problems have been observed that will affect the environment negatively unless regulatory measures are taken. Companies seeking competitive advantages are exploring the use of cheaper more polluting fuels such as pet-coke. The lack of integration between the electrical law and the environmental legislation discriminates against new cleaner sources. The EIA obligates the inclusion of abatement technologies, increasing in the end their marginal abatement costs. This is not the case for existing sources that do not require these controls. Since pet-coke is of low cost, it can displace in the dispatch ranking, cleaner gas fueled plants. As a result, these latter plants may face economic problems.

Of course the authority must balance requesting extra environmental requirements with the ensuing increase in marginal costs and finally energy prices. This is not an easy equation. The authority must determine how much the reduction of an additional kilogram of a polluting gas is worth for society. Additionally, it must find the mechanisms that would allow incorporating this cost into each agents decision-making process. The rapid and hardly predictable changes in the sector, including national and international interconnections of the power grid, strategic considerations by firms, availability of natural gas and increasing public participation, make this a complex task.

References

1 RUDNICK H., SOTO M., PALMA R.: "Use of System Approaches for Transmission Open Access Pricing," Electrical Power and Energy Systems, ELSEVIER, Nº 21, 1999, pp. 125 – 135.

2 FISCHER, R, and GALETOVIC, A: "Regulatory Governance and Chile's 1998 – 1999 Electricity Shortage", Economics Series Working Paper 84, Universidad de Chile, Departamento de Ingeniería Industrial, July 2000.

3 VARGAS, L, PALMA, R and MOYA, O.: "Power Exchange Behavior in a Hydrothermal System: The Chilean Case", Working Paper, Universidad de Chile, Departamento de Ingeniería Eléctrica.

4 FISCHER, R, and SERRA, P.: "Regulating the Electricity Sector in Latin America", Economics Series Working Paper 86, Universidad de Chile, Departamento de Ingeniería Industrial, August 2000.

5 DÍAZ, C, GALETOVIC, A, and SOTO, R.: "La Crisis Eléctrica de 1998 – 1999 Causas, Consecuencias y Lecciones", Economics Series Working Paper 81, Universidad de Chile, Departamento de Ingeniería Industrial, June 2000.

6 VARGAS, L, PALMA, R and MOYA, O.: "Mercados Eléctricos y Bolsas de Energía: Aspectos Críticos para su Implementación en Chile", Working Paper, Universidad de Chile, Departamento de Ingeniería Eléctrica.

7 SEPÚLVEDA, L, and RUDNICK, H.: "Impacto de Costos Ambientales en el Despacho del Sistema Interconectado Central", ICSECIT 2001, International Conference on System Engineering, Communications and Information Technologies , April 17 -19, 2001, Universidad de Magallanes, Punta Arenas, Chile .

8 RUDNICK, H, and QUINTEROS, R.: "Power System Planning in the South America Electric Market Restruturing", VI Symposium of Specialists in Electric Operactional and Expansion Planning – VI SEPOPE, May 24 – 29, 1998, Bahia, Brazil.

9 "Briefing on Chilean electricity law", www.ing.puc.cl/power/southamerica/ChileanLaw.htm

10 RUDNICK, H.: "The Electric Market Restructuring in South Americana: Successes and Failures on Market Desing", Plenary Session, Harvard Electricity Policy Group, January 29 30, 1998, San Diego, California.

11 RUDNICK, H, and ZOLEZZI, J.: "Electric sector deregulation and restructuring in Latin America: lessons to be learnt and possible ways forward", IEE Proc. – Gener. Transm. Distrib. Vol. 148, Nº 2, March 2001.

12 GESTION AMBIENTAL CONSULTORES; “Estimación de los efectos ambientales de la sustitución de combustibles tradicionales (carbón), por pet – coke, en la generación eléctrica y procesos industriales”. Informe preparado para GAS ATACAMA, Santiago, Junio de 1999.

13 COMISIÓN NACIONAL DE ENERGÍA, “National Energy Balance 1979 – 1998, Chile”.

14 WEB SITE COMISIÓN NACIONAL DE ENERGÍA, www.cne.cl.

15 WEB SITE, www.quepasa.cl/revista/2000/07/16/t-16.07.QP.NEG.COKE.html

16 WEB SITE, www.quepasa.cl/revista/2000/07/09/t-09.07.QP.TM.CONTAMINACION.html